

# Monitor and Control Equipment for the MV-3 Mobile Very Long Baseline Interferometry Station

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*A monitor and control system for the MV-3 mobile very long baseline interferometry station has been designed around a commercially available process controller. The significant features of the hardware design and the method by which this equipment will be operated by the MV-3 central computer are discussed.*

## I. Introduction

One of the goals of the MV-3 project (also known as the ORION project) was to utilize existing technology to the greatest extent possible and thereby reduce the amount of engineering required at JPL. An area in which it seemed probable that this goal could be achieved was that of monitor and control where recent advances in the field of industrial process control had provided an abundance of equipment and systems from which to make a selection. By pursuing this approach, JPL engineering was limited to performing the high-level system design, selecting the process control equipment, designing the interface to other subsystems and writing the software to operate the process control equipment from the MV-3 central computer.

## II. MV-3 Monitor and Control System Design

There are four principal monitor and control functions at the MV-3 system level. These are execution of an end-to-end performance test, automation of frequently recurring activities, detection of failures which are not immediately observed by the end-to-end test and analysis of monitor

data for malfunction isolation. The first function was delegated to the digital tone extractor of the Phase Calibration Subsystem. The remaining three were delegated to the Monitor and Control Subsystem to be accomplished either within the subsystem or through orchestration of other subsystems connected to the MV-3 central computer.

Much of the equipment selected for use in the MV-3 station had the capability for automatic control and monitoring via an RS-232C serial interface. This included the antenna servo equipment, the water vapor radiometer, the Mark III Data System and the hydrogen maser. The remaining equipment was either of new design or was not available with built-in monitor and control capability.

The original concept was to provide each major item of equipment in this second category with a small data acquisition system to perform the monitor and control functions. These would provide a standard interface to the MV-3 central computer — a Hewlett Packard 1000 System, Model 40, which is supplied with the Mark III Data System. The disadvantage of this approach was that a considerable amount of redundant

engineering would have been needed to design suitable mechanical, electrical and environmental provisions in each subsystem for the data acquisition equipment. The concept was therefore rejected in favor of a single microprocessor-based process controller on each transporter. Figure 1 illustrates the MV-3 monitor and control system, as implemented, showing the monitor and control interfaces as well as the end-to-end self test signal flow.

### III. Selecting the Process Control Equipment

Selection of the process controllers began with a vendor survey to determine what capabilities were available in commercial equipment. The results were used to create a list of capabilities ranked by the number of vendors who could supply them. Discussions were then conducted with subsystem engineers to determine the minimum subset of capabilities which could fulfill all MV-3 monitor and control requirements. This subset, listed in Table 1, was incorporated into a specification for an "Analog Monitor and Control Assembly" and submitted for competitive procurement.

### IV. Analog Monitor and Control Assemblies

The selected analog monitor and control assemblies are manufactured by Analog Devices of Norwood, MA. under the trade name of MACSYM 20. One of their intended uses is to serve as the interface between a host computer and up to 256 assorted analog or digital monitor or control points. In the MV-3 application, approximately 50-percent of this capacity is used.

As shown in the block diagram (Fig. 2), the analog monitor and control assemblies are designed around an 8-bit, Z80 microprocessor with 16K bytes of random-access read-write memory (RAM) and 16K bytes of read-only memory (ROM).

The microprocessor communicates with the host computer via an RS-232C serial interface and is interfaced to its signal conditioning cards via an analog/digital input/output (ADIO) controller. This controller contains all timing and control logic for addressing the individual signal conditioning cards and a 12-bit successive-approximation A/D converter. Input to the A/D converter is through a sample and hold amplifier, a programmable gain amplifier and a 16-channel multiplexer. This allows a single set of analog-to-digital conversion hardware to be shared by all signal conditioning cards.

In the case of analog and low-level digital signals, the monitor and control interface is by card-edge connectors at the rear of the signal conditioning cards. For digital monitor and control signals in excess of 24 volts, the interface is via an optical

isolation assembly. This assembly permits connection to circuits operating at 90 to 140 Vac and 10 to 60 Vdc. Selection of channel characteristics is made by choosing from among four module types for installation on the optical isolation assembly and by throwing a switch on the appropriate signal conditioning card.

The firmware supplied with the analog monitor and control assemblies provides the capability to interrogate or address the input and output channels either one at a time or in groups of from 2 to 16. This is done by issuing a brief command that includes the action to be taken and the identity and characteristics of the channel or channels. The assembly also has the capability to perform simple mathematical operations and to store an array of parameters and command or operation sequences for later execution by issuing the sequence number.

### V. Subsystem Interfaces

The process of determining a minimum set of capabilities for the analog monitor and control assemblies resulted in the placement of requirements on the various subsystems for selection of transducers and signal conditioning. At the same time, two standard physical interfaces were adopted to decrease inter-subsystem cabling costs. These were a 9 twisted-pair cable with an overall shield to be used for all signals of 50 volts or less and a 12 conductor cable to be used for all signals in excess of 50 volts.

Within each subsystem, monitor points were selected to permit malfunction isolation to replaceable subassemblies. In general this was accomplished by measurement of subassembly outputs — either directly (where the output was a voltage) or using an appropriate transducer to convert the quantity being measured into a voltage. In certain applications, where the subassembly output could not be easily verified, parameters such as input power supply currents were monitored from which subassembly performance could be inferred. Selection of control points was straightforward, with the only decision which needed to be made relating to control status in the event of a momentary failure of the monitor and control equipment. Where it was desirable to keep a function operating in the event of such a failure, a two-signal (switch on, switch off) control scheme was adopted. For other cases a single signal was used.

At the analog monitor and control assembly end, an interface assembly was designed to connect the twist-lock connectors on the inter-subsystem cabling to the printed-circuit card edge connectors required by the signal conditioning cards and the screw terminals on the optical isolation assembly. This

wiring established the relationship between the functions being monitored or controlled and the physical address of that function. This assembly also provided a convenient place to separate analog monitor, digital monitor and digital control signals arriving in one cable from each other.

Table 2 provides a summary of MV-3 monitor and control points which are assessed via the analog monitor and control equipment. Included in this list are the location arm position and meteorological sensor data which are not monitor data but rather part of the station data record. As noted in the table, the list does not include monitor and control data obtained directly by other subsystems.

## **VI. Analog Monitor and Control Assembly Operation**

In order to address a functional monitor or control point it is necessary to know the physical address in the analog monitor and control assembly that is the card and channel number to which the function is connected. It is also necessary to know whether the function is a monitor or a control point, whether it is analog or digital, and, for analog channels, the sensitivity needed to make the measurement.

Fortunately, the command structure for the analog monitor and control assemblies is such that this information can be retrieved from the parameter array by calculating one or more indices into the array. Thus a single integer number corresponding to a function can be transmitted to the analog monitor and control assembly followed by an instruction sequence number. By following the instruction sequence previously

stored, the physical address and characteristics of the function can be determined and the appropriate operation performed. Values of monitor points are returned to the central computer by using additional instruction sequences.

The process of initializing the analog monitor and control assemblies to perform these operations consists of downloading two text files from the central computer. The first file contains command sequences whereas the second file contains the values to be stored in the parameter array. The process is performed once when the central computer software is initialized and again if an expected response is not received. The central computer software is notified of a failure if no response is received after reinitialization.

As data are received they are put into a common area of storage in the central computer. It takes between 15 and 20 seconds to completely update this area with data — the variation being caused by the data values themselves. This technique provides easy access by applications programs which are performing such activities as performance monitoring, station automation and malfunction isolation.

## **VII. Conclusion**

A monitor and control system has been successfully designed and implemented using two industrial process controllers. The amount of engineering effort to support this activity has proven to be in close agreement with initial estimates. Additional benefits are expected during the development of applications software because of the versatility of the command language firmware provided with these controllers.

## **Bibliography**

1. Brunn, D. L., et al., "ORION Mobile Unit Design," in *TDA Progress Report 42-60*, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1980.
2. Sigman, E. H., and Parks, G. S., "Use of a Digital Tone Extractor for Real-Time Phase Analysis," in *Proc. of the 1979 American Geophysical Union/NASA Conference on Radio Interferometry Techniques for Geodesy*.

**Table 1. Minimum capability list for MV-3 monitor and control**

Parameter	Required capability
Analog input	
Number of channels	64
Configuration	Differential
Sensitivities	0 to $\pm 10$ Vdc and 0 to $\pm 1$ Vdc <sup>(1)</sup>
Resolution	12-bit
Digital input	
Number of channels	50
Logic levels supported	TTL, 26 Vdc/0 Vdc, 115 Vac/0 Vac
Simultaneous read capability	16 channels
Digital output	
Number of channels	27
Logic levels supported	115 Vac @ 1.8 Aac, 26 Vdc @ 1.8 Adc
Physical	
Configuration	Rack mount with slides
Maximum dimensions	266 mm (10.5") H $\times$ 521 mm (20.5") D <sup>(2)</sup>
Environmental	
Operating temperature	0 to 45°C
Storage temperature	-45 to 66°C
Operating altitude	Sea level to 3048 m (10,000 ft)

(1) Selected unit has sensitivities of  $\pm 10$ ,  $\pm 5$ ,  $\pm 7.5$ ,  $\pm 1.25$ ,  $\pm 0.625$  Vdc, etc., to  $\pm 4.88$  mVdc  
(2) Selected unit vertical dimension is 222 mm (8.75")

**Table 2. MV-3 monitor and control points**

Subsystem and assembly	Monitor points	Control points
<b>Microwave Subsystem</b>		
Low-noise amplifiers	5	4
Cryogenics	6	7
Power supplies	2	—
Miscellaneous	3	—
<b>Receiver Subsystem</b>		
Down-converters	9	—
Power supplies	6	—
<b>Phase Calibration Subsystem</b>		
Cable stabilizer	6	—
Comb generators	2	2
Noise adding radiometer	—	1
Power supplies	8	—
<b>Antenna Subsystem<sup>(1)</sup></b>		
Locator arm	9	2
Emergency stop/movement warning	1	2
<b>Facilities Subsystem</b>		
Power generation	5	—
Power distribution	2	10
Environmental control	22	—
<b>Data Acquisition Subsystem<sup>(2)</sup></b>		
Mark III Data System	9	—
recorders	22	—
<b>Frequency and Timing Subsystem<sup>(3)</sup></b>		
Distribution amplifiers	4	—
Cesium standard	3	—
Instrumentation	1	—
<b>Meteorological equipment</b>		
Sensor data	4	—
Power supplies	4	—
<b>Water vapor radiometer<sup>(4)</sup></b>		

**NOTES:**

- (1) Monitor and control of antenna controller and servos are by self-contained equipment.
- (2) Configuration monitor and control of Mark III Data System and recorders are by self-contained equipment. Listed monitor points are power supply voltages.
- (3) Monitor and control of hydrogen maser, frequency standard room temperature monitor and part of the frequency standard performance monitor are by self-contained equipment.
- (4) Monitor and control of water vapor radiometer is by self-contained equipment.

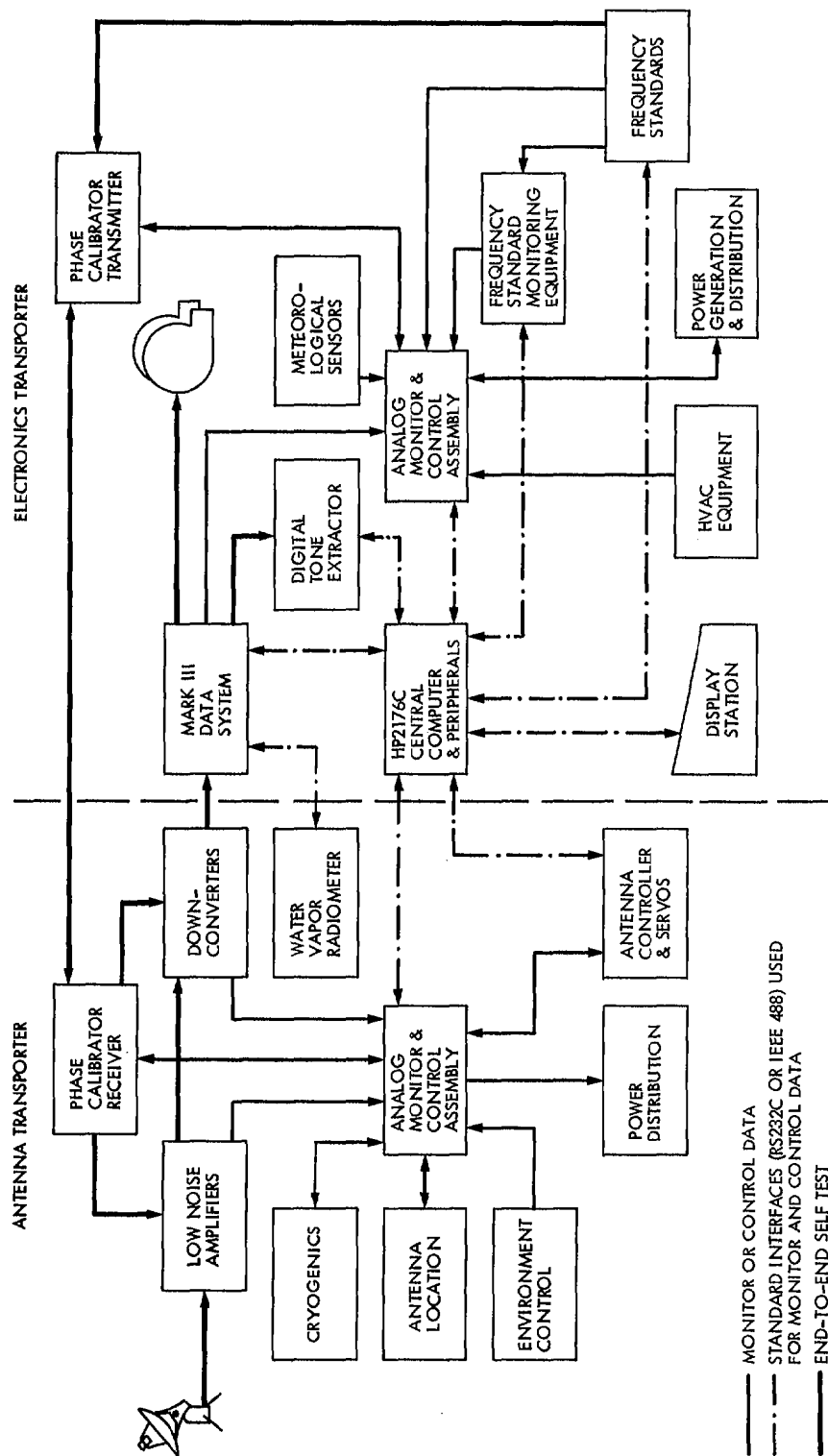


Fig. 1. MV-3 equipment/MV-3 monitor and control interconnections

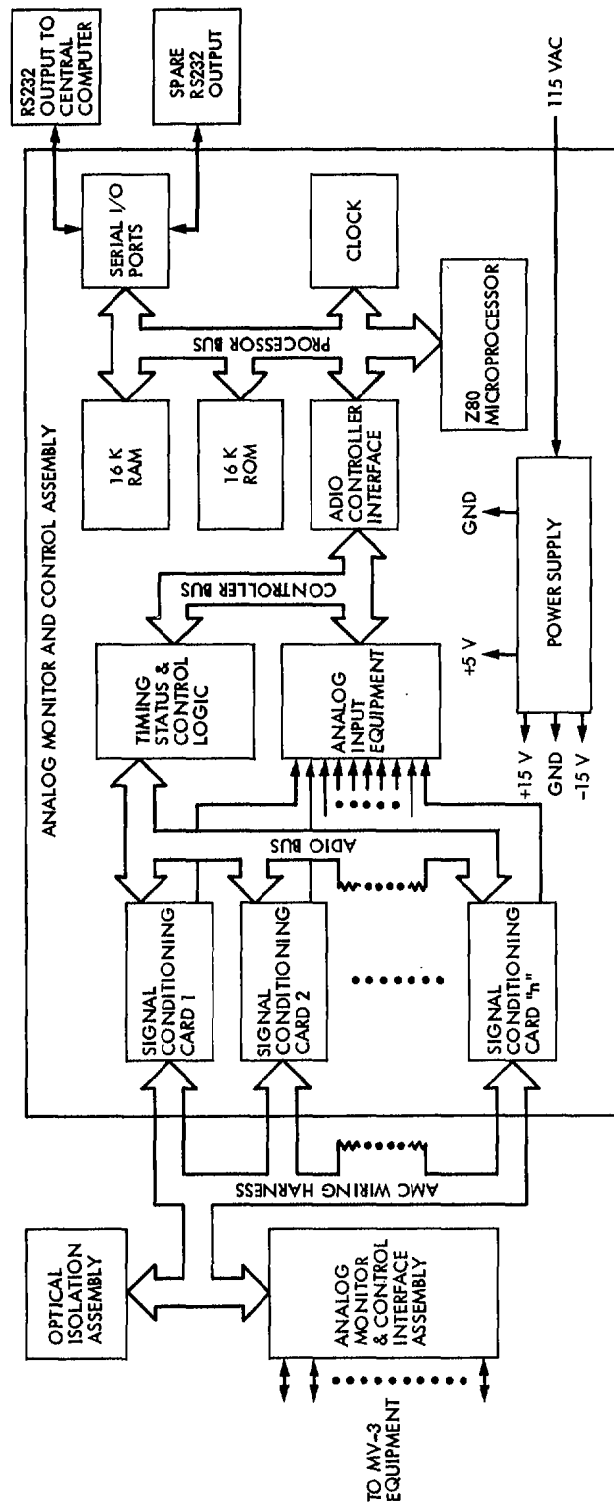


Fig. 2. Analog Monitor and Control Assembly block diagram